Update of "First measurement of $\chi_{cJ} \to \Sigma^{+}\overline{p}K_{S}^{0} + c.c$(J=0, 1, 2) decays"

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Event topology

$$\psi(3686) \to \gamma\chi_{cJ}, \chi_{cJ} \to \Sigma^+ \bar{p} K_S^0 + c.c$$

($K_S^0 \to \pi^+\pi^-$, $\Sigma^+ \to p\pi^0$)

- Final states of signal: $\gamma\gamma\gamma p\bar{p}\pi^+\pi^-$.
- In the next slides, the charge-conjugated channel is included by default.

Q1: If Ntrack>4?

- **Charged tracks**
  - No |Rxy | and |Rz| requirements;
  - |cosθ|<0.93;
  - Ngood = 4 & ΣQ=0;

4 ≤Ngood ≤ 6

- **Neutral tracks**
  - E≥25 MeV for barrel (|cosθ|< 0.8);
  - E≥50 MeV for endcap (0.86<|cosθ|< 0.92) ;
  - θmin(γ,charge)>10°;
  - 0<TDC<14 (50ns) ;
  - Nγ≥3;
- **PID**
  - PID for proton;

- **4C kinematic fit**
  - With the smallest χ^2
  - Obtain $\gamma\gamma\gamma p\bar{p}\pi^+\pi^-$
- **K_S is reconstructed by Second VertexFit**

$$L/\sigma_L > 2$$

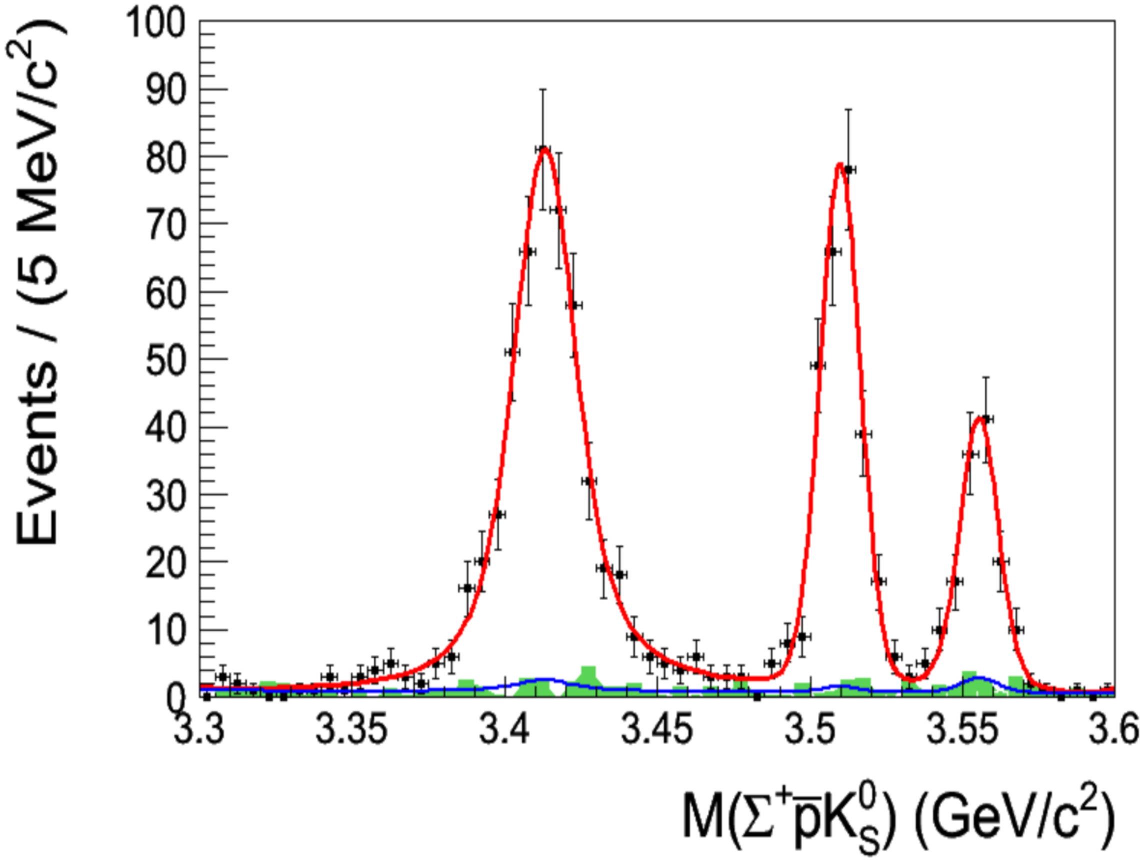
- **$\pi^0$and radiative γ_3:**

$$\chi^2 = \left(\frac{M(\gamma_1\gamma_2) - M(\pi^0)}{\sigma_{\pi^0}}\right)^2$$

The left γ_3 is as the radiative γ from $\psi(3686)$.

- **Suppress background with $\gamma\gamma$ or $\gamma\gamma\gamma\gamma$ in final states:**

$$\chi^2(\gamma\gamma\gamma\pi^+\pi^-)<\chi^2(\gamma\gamma\gamma\gamma\pi^+\pi^-)$$
$$\&\&\ \chi^2(\gamma\gamma\gamma\pi^+\pi^-)<\chi^2(\gamma\gamma\pi^+\pi^-)$$



- The background is basically unchanged.
- Peaking Bkg: 10, 2.4, 7.4

→ **11, 2.9, 7.5**

The comparison between the two results

$Ngood = 4$	Efficiency	Nsignal	Branching Fraction($\chi_{cJ} \to \Sigma^{+}\bar{p}K_S + c.c$) (*10^{-4})
χ_{c0}	9.26%	491 ± 26	$3.36 \pm 0.18 \pm 0.21$
χ_{c1}	10.88%	259 ± 17	$1.58 \pm 0.103 \pm 0.09$
χ_{c2}	10.26%	129 ± 13	$0.874 \pm 0.088 \pm 0.052$

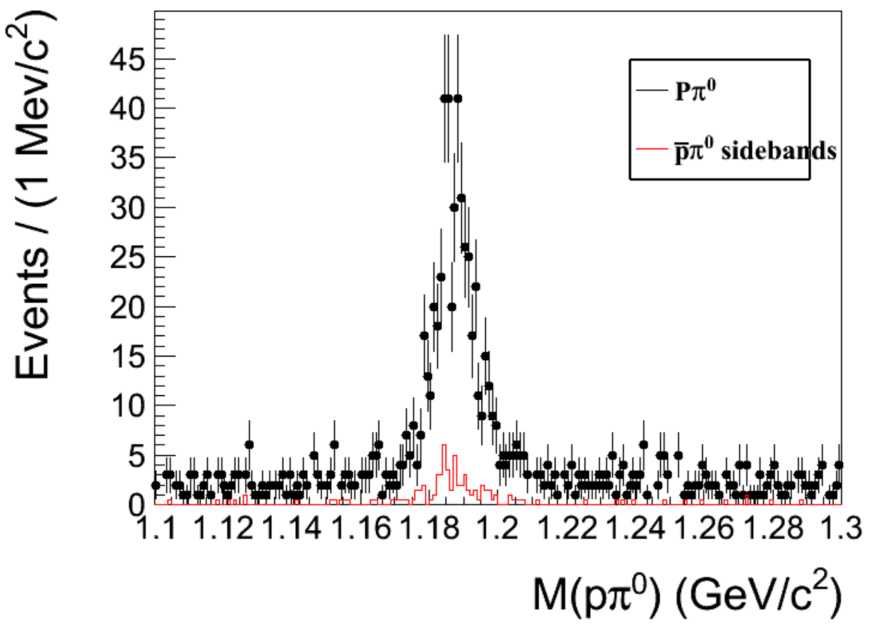
$4 \leq Ngood \leq 6$	Efficiency	Nsignal	Branching Fraction($\chi_{cJ} \to \Sigma^{+}\bar{p}K_S + c.c$) (*10^{-4})
χ_{c0}	9.56%	509 ± 26	$3.37 \pm 0.17 \pm 0.19$
χ_{c1}	11.23%	262 ± 17	$1.55 \pm 0.10 \pm 0.08$
χ_{c2}	10.57%	132 ± 13	$0.868 \pm 0.085 \pm 0.047$

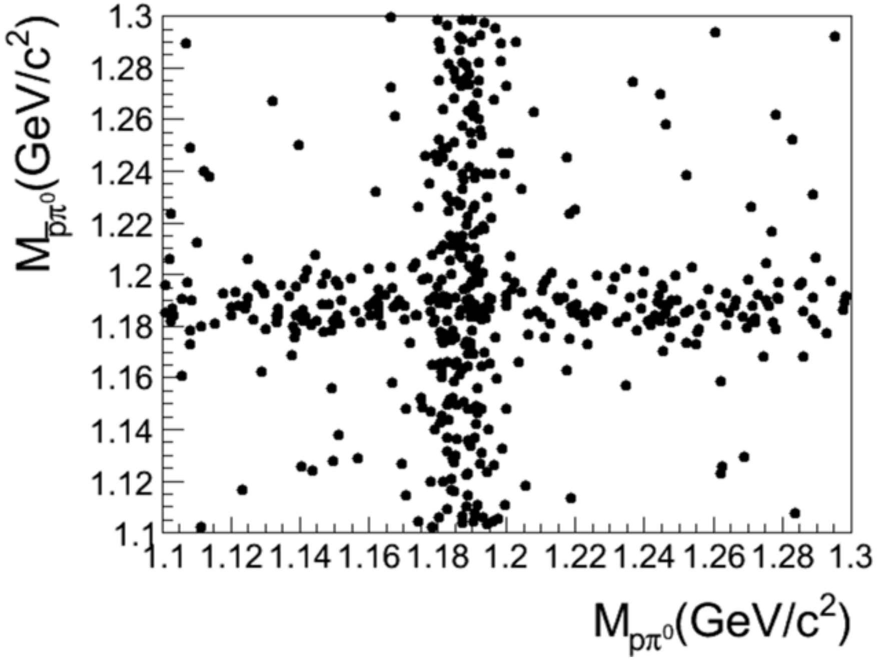
consistent

In the updated memo, we use the selection: $4 \leq Ngood \leq 6$

Q2:Why not perform 5C to $p\pi^0$?

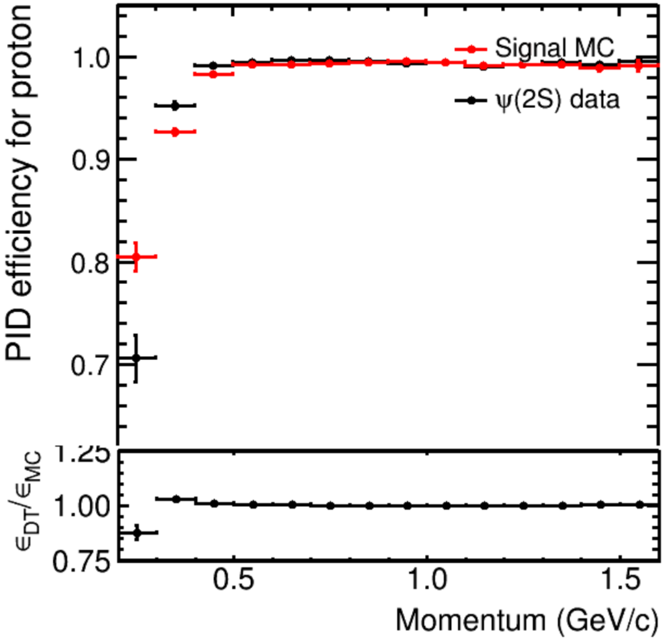
Answer： We need to use the $\bar{p}\pi^0$sidebands to estimate the background under the $p\pi^0$ $mass$.
So, we prefer not to do the 5C.

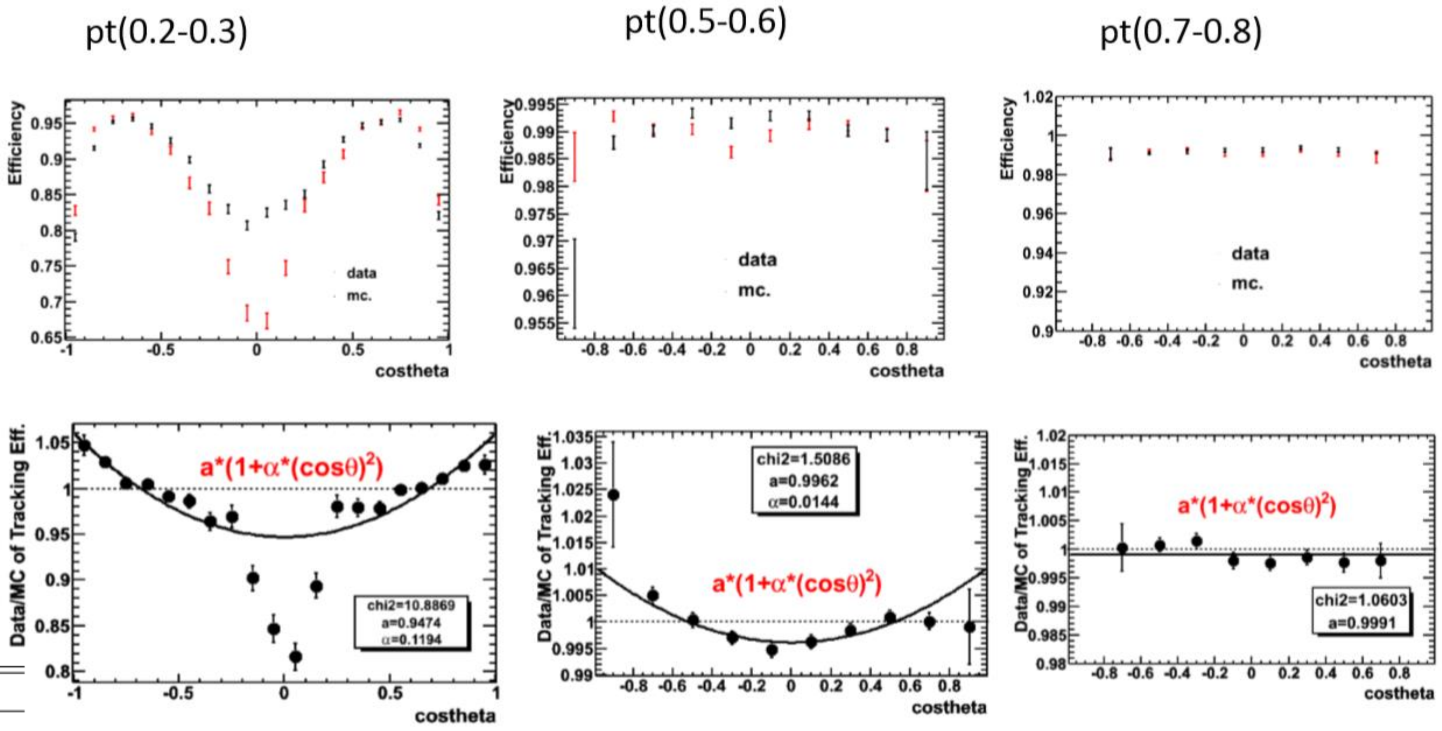




Q3:Systematic uncertainties of PID and tracking of p($\bar{p}$)

Using the control sample $\psi(3686)$ (J/ψ)$\rightarrow\bar{P}P\pi^{+}\pi^{-}$





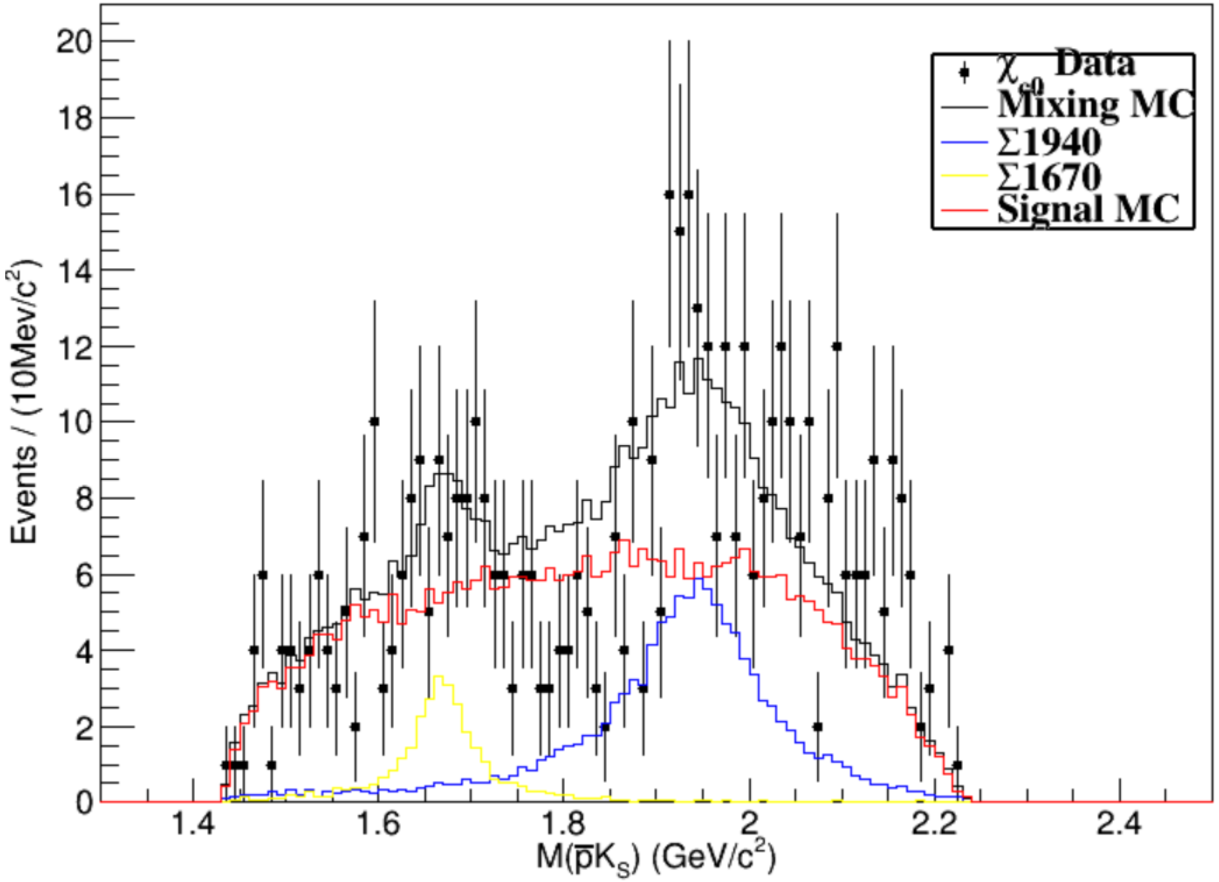
$\epsilon^{p-trackandpid}(MC)$	(0.2,0.3)	(0.3,0.4)	(0.4,0.5)	(0.5,0.6)	(0.6,0.7)	(0.7,0.8)
(-0.93,-0.8)	103.46 ± 0.48	101.25 ± 0.31	100.66 ± 0.38	102.40 ± 0.99	1 ± 0	1 ± 0
(-0.8,-0.6)	100.35 ± 0.32	100.33 ± 0.15	100.11 ± 0.15	100.49 ± 0.15	100.13 ± 0.22	100.03 ± 0.41
(-0.6,-0.4)	99.08 ± 0.53	100.02 ± 0.19	99.79 ± 0.14	100.03 ± 0.13	100.20 ± 0.14	100.08 ± 0.13
(-0.4,-0.2)	96.73 ± 0.86	99.68 ± 0.21	99.73 ± 0.14	99.71 ± 0.12	100.23 ± 0.13	100.14 ± 0.14
(-0.2,0)	87.62 ± 1.13	97.93 ± 0.28	99.14 ± 0.18	99.47 ± 0.15	99.76 ± 0.14	99.80 ± 0.14
(0,0.2)	85.33 ± 1.09	98.81 ± 0.26	99.55 ± 0.17	99.63 ± 0.13	99.84 ± 0.13	99.76 ± 0.14
(0.2,0.4)	98.07 ± 0.86	99.90 ± 0.21	100.04 ± 0.16	99.85 ± 0.12	100.04 ± 0.13	99.85 ± 0.13
(0.4,0.6)	98.41 ± 0.51	100.17 ± 0.18	99.88 ± 0.14	100.09 ± 0.14	100.14 ± 0.14	99.77 ± 0.17
(0.6,0.8)	100.71 ± 0.33	100.20 ± 0.15	100.59 ± 0.15	100.01 ± 0.16	99.81 ± 0.22	99.80 ± 0.30
(0.8,0.93)	102.46 ± 0.44	100.73 ± 0.30	100.56 ± 0.37	99.91 ± 0.71	1 ± 0	1 ± 0

So there is much cosΘ dependence of p tracking and pid efficiency between data and mc when the transverse momentum is less than 0.6 GeV.

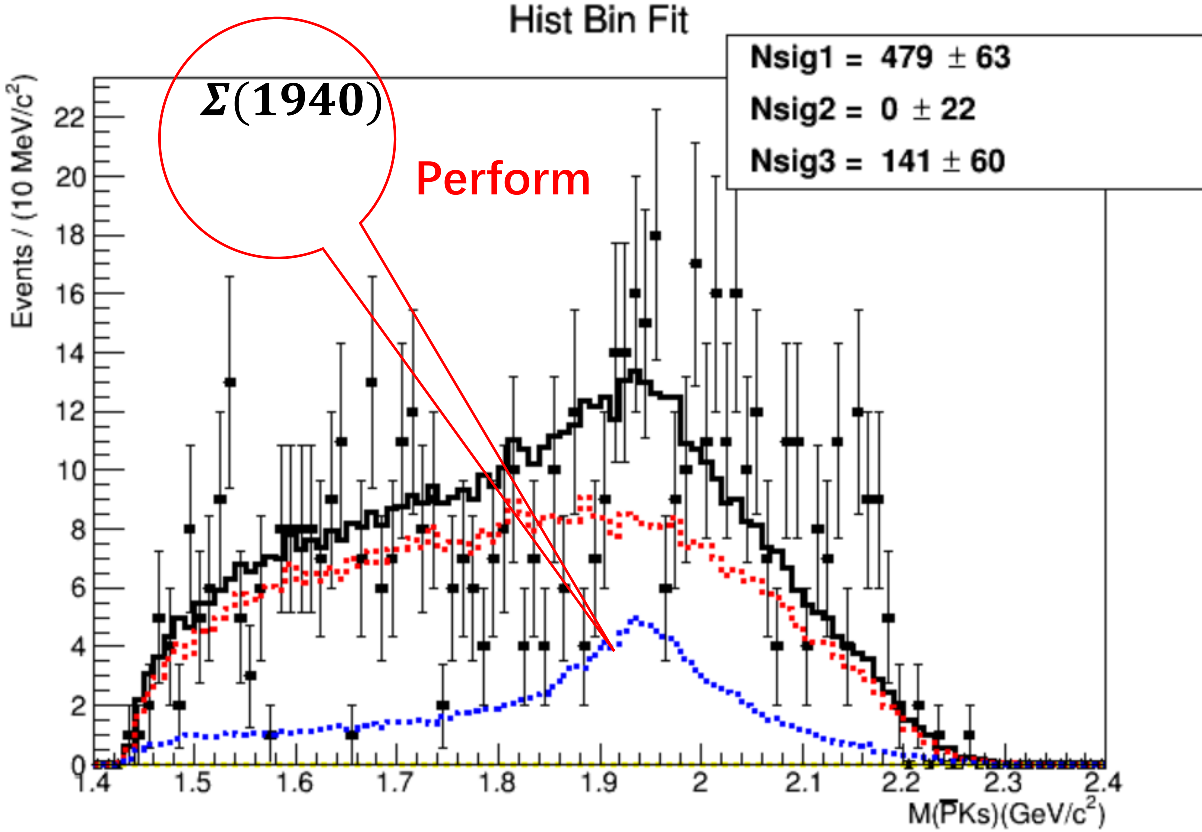
The systematic error of this item is reduced from3.7%,3.8%,4.0% to 2.6%,2.3%,3.0%.

Q4:Systematic uncertainties of the intermediate resonances

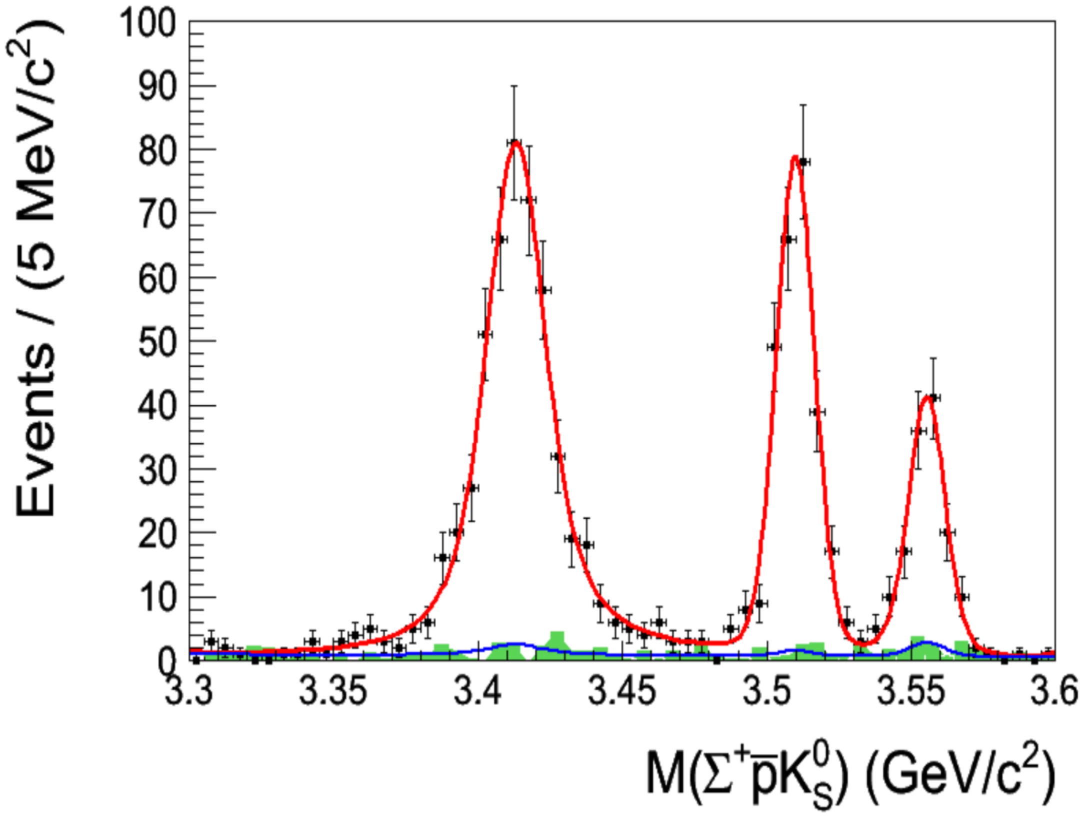
We add $\Sigma(1940)$ *and* $\Sigma(1670)$.The uncertainty of the efficiency is 0.3%.



The uncertainty is 0.1%.



Q5:Systematic uncertainties of $\boldsymbol{\beta}$



$$PDF = (\mathbf{BW(m)} \times \mathbf{E}_{\gamma}^{3} \times \mathbf{D}(E_{\gamma})) \otimes \mathbf{Gaussion}$$

$$E_{\gamma} = \frac{M_{\psi(3686)}^2 - m^2}{2M_{\psi(3686)}}$$

$$\mathbf{D}(E_{\gamma}) = e^{-\frac{E_{\gamma}^2}{8\beta^2}}$$ [1]

[1] R. E. Mitchell et al. (CLEO Collaboration), Phys. Rev. Lett. 102, 011801 (2009)

$$\beta = 65 \pm 2.5 \text{ MeV}$$

β	channel	65	62.5	67.5
channel	χ_{c0}	508 ± 26	507	509
	χ_{c1}	260 ± 17	260	261
	χ_{c2}	132 ± 13	132	133

Systematic uncertainties

Summary of systematic uncertainty sources and their contributions (in %).

Source	$\mathcal{B}(\chi_{c0})$	$\mathcal{B}(\chi_{c1})$	$\mathcal{B}(\chi_{c2})$
pion tracking	2.0	2.0	2.0
Photon detection	3.0	3.0	3.0
P($\bar{P}$)Particle ID and tracking	2.6	2.3	3.0
4C kinematic fit	0.4	0.3	0.3
π^0 mass window	0.3	0.3	0.3
K_S^0 mass window	0.3	0.3	0.3
Σ^+ mass window	0.1	0.1	0.1
$\bar{\Sigma}^-(1940)$ structure	0.1	...	...
Signal line shape	1.2	2.3	0.3
changeβ	0.2	0.4	0.8
Fit range	0.8	0.8	2.0
2D-sideband	0.4	0.1	0.8
Remaining background shape	3.1	0.7	1.5
Intermediate decay	0.4	0.4	0.4
Number of $\psi(3686)$	0.6	0.6	0.6
Total	5.7	5.1	5.5

Summary

- $\chi_{cJ} \rightarrow \Sigma^+\bar{p}K_S^0 + c.c$ is performed for the first time, the branching fractions of them are given.

4 ≤Ngood ≤ 6	Efficiency	Nsignal	Branching Fraction($\chi_{cJ} \rightarrow \Sigma^+\bar{p}K_S + c.c$) (*10^{-4})
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- The memo is ready and will be released very soon.